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SOIL-MANAGEMENT AND CROP-PRODUCTION STUDIES

Carbon County Area

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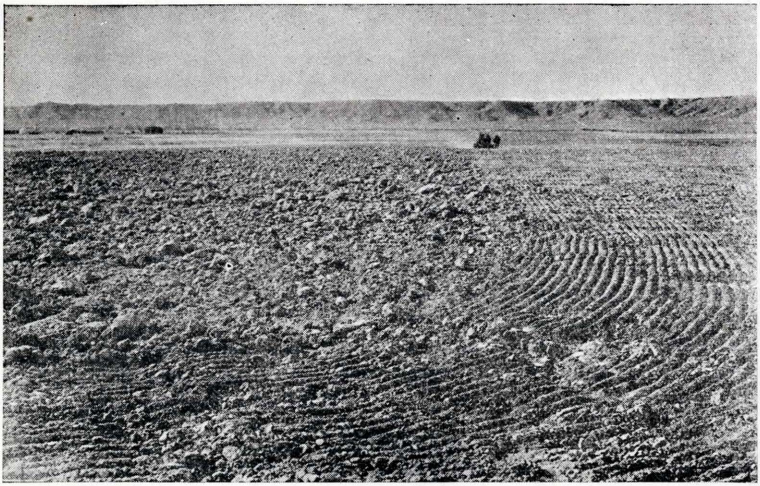

Figure 1.—Showing effects from use of cultipacker, Carbon County Experimental Farm

UTAH AGRICULTURAL EXPERIMENT STATION

UTAH STATE AGRICULTURAL COLLEGE

Logan, Utah

Soil-Management and Crop-Production Studies[1]

Carbon County Area

I. D. ZOBELL[2]

CARBON COUNTY AND ITS RELATION TO AGRICULTURAL INVESTIGATIONS

General Statement

Carbon County is the greatest bituminous coal-producing district in the state and ranks as one of the largest and best in the Intermountain West. In 1934[3] there were twenty-six operating coal mines from which approximately 5,000,000 tons of coal were mined each year. These mines create work for hundreds of men. Many people in this section farm in the summer and mine during the winter months. In 1934 but 20,000 acres of land in this section were under cultivation, with little possibility of reclaiming additional land. Prior to 1928 crops had been somewhat restricted on account of the limited water-supply; this difficulty, however, was overcome with the construction of the Horsley Dam located in Pleasant Valley. This dam forms a lake 4 miles long and 1 mile wide and furnishes sufficient irrigation water for all land on the new project.

By a special act of the State Legislature in 1927 the Carbon County Experimental Farm was established[4]. This 40-acre farm was located on a new irrigation tract south of the Price River and approximately 4 miles south of Price, the county seat, in a region where the agricultural resources had been only partially developed.

Topography

The general slope of the land in this section is toward the east and south. The region is slightly rolling, interspersed with numerous mesas which are considerably higher than the surrounding country. Because of the peculiar eroded sides of these mesas the entire section is locally

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[1]Contribution from Department of Agronomy, Utah Agricultural Experiment Station.

[2]Former Assistant Agronomist and Superintendent Carbon County Experimental Farm, from 1927 to 1933, inclusive.

[3]This manuscript was submitted for publication by the author, early in 1934, soon after the discontinuance of the Farm.

[4]Due to lack of funds, the Carbon County Experimental Farm, together with other Station outlying experimental farms, was discontinued in 1933.

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known as Castle Valley, which in reality is a series of small valleys.

Climatological Factors

From the time of its establishment in 1927 climatological records were kept at the Carbon County Experimental Farm. Temperature data were recorded in a standard United States Weather Bureau gage. Wind velocity was determined from a standard three-cup anemometer, exposed at a height of 36 inches. Evaporation was recorded by daily micrometer measurements in a tank 24 inches deep and 6 feet in diameter, sunk to a depth of 20 inches in the ground.

Table 1.—Monthly and annual precipitation (in.), inclusive, Carbon County, Utah. (Records taken from the United States Weather Bureau).

	Month												
Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1920	0.51	1.05	1.14	0.99	0.95	0.25	0.10	2.82	0.15	1.78	0.25	0.74	10.73
1921	1.66	0.48	0.22	0.46	1.91	1.16	0.81	4.32	0.22	0.47	0.08	1.95	13.74
1922	0.85	0.81	1.34	0.92	1.53	0.47	0.94	1.19	0.05	0.59	0.65	1.28	10.62
1923	1.01	0.77	0.05	1.69	0.77	0.02	....	....	0.15	0.76	0.70	0.57	.....
1924	0.68	....	....	0.00	0.52	0.00	1.00	0.40	1.20	1.20	0.85	1.35	.....
1925	0.20	0.23	....	....	....	2.74	1.32	2.85	2.43	2.31	0.23	0.38	.....
1926	0.08	0.74	1.09	1.50	0.25	0.30	0.94	0.83	0.68	0.08	0.98	0.86	8.33
1927	0.48	1.93	....	0.33	0.00	3.69	1.92	2.71	5.91	0.77	0.34	0.47	.....
1928	0.29	0.63	0.85	0.20	1.46	0.21	0.41	0.75	0.53	2.33	1.08	0.29	9.03
1929	0.79	0.43	1.45	0.46	0.35	0.10	0.94	2.10	3.07	1.00	0.00	0.20	10.89
1930	1.32	0.42	1.10	0.74	0.80	0.73	0.71	3.45	1.47	0.47	0.75	0.00	11.96
1931	0.06	0.65	0.28	0.91	0.20	0.18	0.89	1.00	0.08	0.91	0.91	0.53	7.64
1932	0.82	0.83	0.24	0.95	0.70	0.70	2.99	1.92	0.21	0.35	0.00	0.51	10.22
1933	1.78	0.10	0.08	0.65	1.12	0.00	2.11	0.30	0.70	0.30	1.03	1.08	6.94
Avg.	0.75	0.69	0.71	0.75	0.81	0.75	1.16	1.89	1.20	0.95	0.56	0.72	10.94

As indicated in Table 1, the heaviest precipitation in this region usually occurs during July, August, and September and lightest during November, February, and March. Because of the heavy rainfall during July, August, and September, considerable damage may occur on crops ready to be harvested during these months. Frequently the heavy midsummer rainfall is in the form of cloudbursts as much as 2 inches falling in a two-hour period. Because of the nature of the soil in this region, torrential floods frequently occur, resulting in considerable damage. The light spring rainfall makes pre-irrigation necessary for many crops. Frequently no precipitation has been recorded during April, May, June, November, and December. Precipitation has often occurred in different and not in successive years. Because of the nature of the soil, more harm than good has frequently resulted from spring rains, since these rains often form a crust on the soil with consequent difficulty for seedling emergence.

Table 2 shows the average mean temperature for this section from 1920 to 1933, inclusive, in which it is observed that there is little fluctuation in temperature during the crop-growing period from April to October. The comparatively high temperatures of July and August are conducive to the production of certain crops.

Table 2.—Average mean temperature(°F.), 1920-33, inclusive, Carbon County, Utah. (Records taken from United States Weather Bureau).

Year	Month												Avg. for Year
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
1920	20.0	32.4	36.2	40.8	58.0	64.6	71.8	68.2	61.0	54.0	44.7	28.3	48.3
1921	23.4	35.0	41.6	44.2	55.5	66.8	71.0	66.8	59.2	54.8	37.8	31.2	48.9
1922	17.8	24.4	35.4	41.8	55.2	67.0	71.6	70.4	63.2	46.0	32.0	26.7	46.0
1923	25.5	22.6	35.0	45.2	57.4	62.2	....	....	56.4	45.2	37.4	25.0	....
1924	17.2	....	....	43.4	58.7	65.1	73.4	68.0	60.6	54.2	38.5	18.2	....
1925	11.0	35.6	....	....	....	64.2	73.9	69.0	60.0	49.4	35.8	30.4	....
1926	27.8	35.1	42.4	53.4	59.5	68.9	71.4	71.0	62.2	54.2	39.5	24.6	50.8
1927	26.2	33.2	....	48.8	57.0	66.5	72.4	67.8	60.2	51.2	40.4	23.6	....
1928	28.8	33.4	42.7	45.8	60.1	62.3	70.0	68.6	61.4	51.0	37.2	23.4	48.7
1929	20.7	25.2	37.9	44.5	56.6	63.6	72.4	71.8	59.8	51.6	33.9	28.8	47.2
1930	14.0	30.6	39.7	52.9	53.8	66.2	73.0	69.9	59.6	48.2	35.7	24.4	47.3
1931	26.5	36.2	38.2	49.8	56.8	68.6	76.6	72.4	63.6	52.4	33.2	18.3	49.3
1932	14.0	30.0	38.0	47.8	56.8	65.4	73.0	70.0	63.9	48.4	37.2	19.8	46.1
1933	18.1	14.3	39.9	44.2	51.8	69.2	75.6	71.2	64.6	55.0	38.5	31.0	47.8
Avg.	20.7	29.8	38.8	46.3	56.7	66.4	72.7	69.6	61.1	51.1	37.2	27.2	48.1

During the 14-year period from 1920 to 1933, inclusive, the average length of the growing season(frost-free days) was 134 days. The average date of the last killing frost in the spring was May 19 and the average date of the first killing frost in the fall was September 30. The earliest date of the last killing frost in the spring was April 13(in 1926) and the latest was July 3(in 1921). The earliest date of the first killing frost in the fall was September 17(in 1924) and the latest was October 15(in 1933). The shortest frost-free period was 80 days(in 1921) and the longest was 156 days(in 1932 and again in 1933). Data for each year from 1920 to 1933, inclusive, are given in Table 3.

Table 3.—Dates of last killing frost in spring and first in fall as well as number of frost-free days, Carbon County, 1920-33, inclusive.

Year	Last Frost in Spring	First Frost in Fall	Frost-free Period (days)	Year	Last Frost in Spring	First Frost in Fall	Frost-free Period (days)
1920	May 2	Sept. 26	147	1927	May 30	Sept. 27	120
1921	July 3	Sept. 21	80	1928	May 4	Oct. 4[1]	153
1922	May 11	Oct. 5[1]	146	1929	May 29	Oct. 4	128
1923	June 1	Sept. 28	119	1930	May 23	Sept. 26	126
1924	June 13[1]	Sept. 17	96	1931	May 11	Sept. 21	132
1925	....	Sept. 30	...	1932	May 6	Oct. 9	156
1926	April 13[1]	....	...	1933	May 13	Oct. 15	156
				Avg.	May 19	Sept. 30	134

[1]Temperature 32° or lower but no frost reported.

There is always more wind in the early spring months than during any other part of the season. Most of the wind during the spring months occurs from 9 a.m. to 5 p.m., there being little wind movement during the night. High wind velocities during the spring months often cause damage by soil-blowing. The constant blowing of the wind each day and the lack of precipitation during the spring of the year often makes frequent irrigation necessary.

Table 4.—Monthly evaporation and wind velocity, Carbon County Experimental Farm, from April to October, 1930-33, inclusive.

	Month							Seasonal
Year	April	May	June	July	August	Sept.	Oct.	Apr. to Oct.
				Evaporation (in.)				
1930	5.75	7.25	6.37	5.25	3.68	2.74	3.10	34.14
1931	4.65	6.40	8.40	8.76	7.80	6.24	4.20	46.45
1932	4.72	6.27	7.76	6.51	4.39	5.63	3.89	39.17
1933	4.31	6.55	8.24	6.38	5.74	5.09	4.18	40.59
Avg.	4.86	6.61	7.69	6.73	5.40	4.92	3.84	40.08
				Wind Velocity (miles per haur)				
1930	2.74	3.37	2.52	2.39	1.57	1.68	1.83	.....
1931	4.00	4.51	3.15	3.83	3.02	3.50	1.76	.....
1932	5.17	4.38	4.53	4.02	4.00	2.56	2.31	.....
1933	5.31	5.72	4.56	4.10	3.81	2.63	2.15	.....
Avg.	4.30	4.49	3.69	3.58	3.10	2.59	2.01	.....

GENERAL CHARACTER OF CARBON COUNTY SOILS

The soils of this area, which have been developed under desert conditions, are usually treeless, except on the mesas which are covered intermittently with juniper(*Juniperus utahensis*) and pinion pine(*Pinus edulis*). Rainfall has not been sufficient to leach and remove lime and other soluble materials. Surface soils contain sufficient carbonate to effervesce in acid and the subsoil contains a layer of lime carbonate in concentrated form.

These soils have been classified by the United States Department of Agriculture, Bureau of Chemistry and Soils, as belonging to the Billings series, which is generally known as a very fine sandy loam. The soil is usually free from gravel, except for limited quantities on the surface in places where it has been washed down from surrounding higher slopes and mesas. Most of the soil forms a mantle of varying thickness over Mancos shales.

Because of the more or less heavy texture of most of the surface soil, most of the rainfall tends to run over the surface. Surface drainage is generally good, but the heavy compacted subsoil and the underlying shale greatly retard moisture movement.

The use of irrigation water has increased the amount of alkali salts in the soil, because of large amounts of soluble salts present in the underlying shales. On farms which have been farmed and irrigated for one or more seasons some alkali salts are present in the soil. Organic matter in these soils is comparatively low, making their management somewhat difficult for most satisfactory results. The soils tend to absorb moisture slowly, which increases the irrigation problem. Clodding results if the soil is tilled when it is either too dry or too wet. The range in moisture content at which tillage may be performed in these soils is limited.

Experiments conducted on the Carbon County Farm definitely proved that the addition of humus to these soils greatly improved their tilth. Humus, either in the form of barnyard manure or of green manure, causes the soil to absorb moisture more readily and to retain it for a longer period of time. The percentage of organic matter in these soils ranges from 0.9 to 2 per cent, depending on the amount of humus which has been added, while the percentage of organic matter in some of the best farming districts of the state ranges from 2 to 3 per cent. The addition of humus to the soil materially increases crop yield and decreases soil-management problems. Few farms in this section have enough livestock even to partly supply the necessary humus to the soil.

ALKALI PROBLEMS IN CARBON COUNTY

One of the most important problems of soil management in any area is the proper handling of alkali soils. On all irrigated farms in this section, soil alkali is present to a greater or lesser degree and its successful treatment is a matter of major importance. Most of the farms in this region contain alkali in menacing amounts. Because of the increasing amounts of alkali in some localities in this region, productive farms of a few years ago are now idle, fertile fields having been transformed into barren alkali flats. These results have come about largely because of seepage, over-irrigation, and under-drainage. The alkali salts of this section usually consist largely of sodium sulphate, sodium chloride, and sodium carbonate, or a mixture of these materials.

The spread of alkali is generally conceded to be directly associated with high water-table conditions, frequently caused by over-irrigation and canal seepage. In this region it is thought that many alkali spots are the direct result of natural barriers which prevent the groundwater from moving toward a lower level. This accumulation of alkali in localized areas has so deflocculated and cemented together the soil particles as to render water penetration or movement of underground water almost impossible.

CARBON COUNTY EROSION PROBLEMS

The soil in this section is especially adaptable for erosion. The extremely fine sandy loams absorb water slowly, with runoff materially higher than on a coarse soil. Soils which are low in organic matter absorb water slowly. thus allowing a much larger percentage of runoff than is the case of soils well-supplied with organic matter. The slope of the land has a direct influence on the amount of erosion which takes place. The occurrence of occasional torrential rains is also responsible for considerable erosion.

In this section most erosion occurs in the form of gullies, locally known as arroyos. There is some sheet erosion, but this is not as important a factor in this area as is gully erosion. In some irrigated sections gullies have been started by allowing waste water to run in the same place for a long period of time. If results from careless irrigation practices could be foreseen and a little time spent in checking the small gully, the larger gully might be prevented. After a gully has been formed, it continues to enlarge with each succeeding rain or influx of waste water. The gully usually makes its first appearance at the lower end of a depression because of the larger volume of water at that point. As the eroding action of the water increases, the steepness of the slope becomes greater and greater and the gully becomes larger and larger.

In the immediate neighborhood where the Experimental Farm was located is a gully which, during the past several years, has cut back several hundred feet. There are several other gullies in this region, many of which are from 100 to 200 feet wide and from 10 to 70 feet deep. In flood periods the water has undercut the banks and caving is not uncommon. Occasionally, irrigation water has broken from the ditch and has run into a nearby gully; within a short time considerable damage has resulted.

On certain lands in this particular section of Utah, gully erosion is occurring at an alarming rate. When gullies have cut down to the underlying shale, an undermining process begins, causing huge blocks of soil to cave into the trenches. These blocks melt rapidly with subsequent floods. This rapid increase of gully erosion greatly endangers surrounding farm-

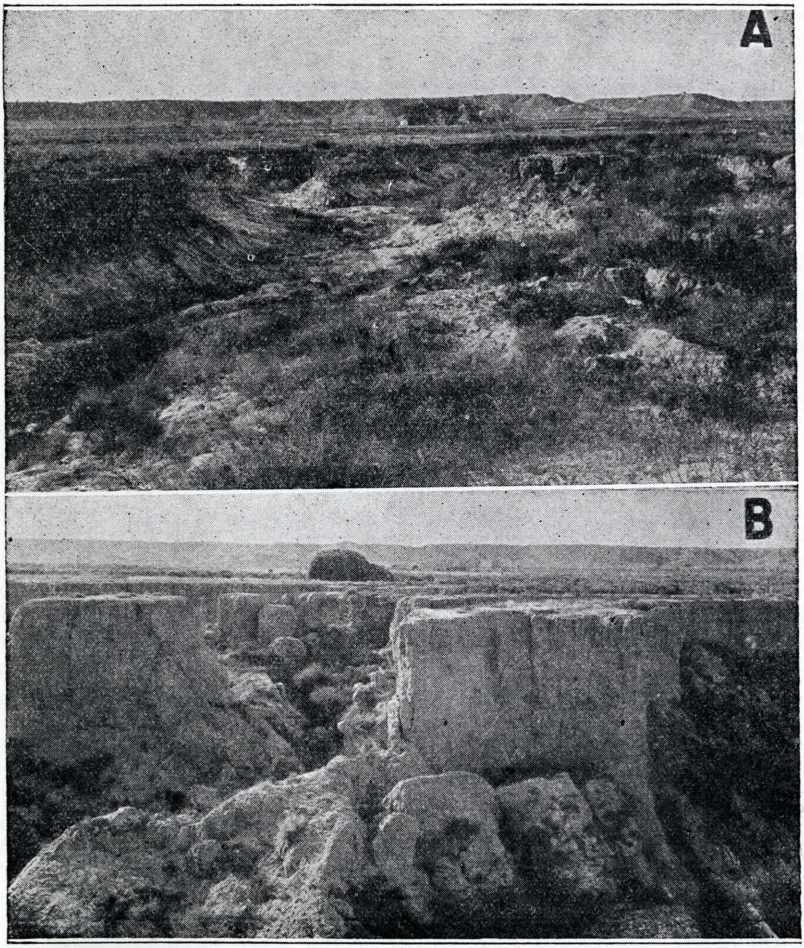

Figure 2.—A. Beginning of a gully in early stages of erosion **B.** Advanced stage of same gully in later stages of erosion.

ing lands; it also destroys land which was once valuable for grazing purposes. Over-grazing by sheep and goats is largely responsible for erosion in the Carbon County Area.

The use of irrigation water on newly-plowed lands is responsible for much valuable land being eroded away, which can be controlled in large measure (1) by using smaller streams of water for irrigation and (2) by exercising more care in irrigating at the beginning of the cropping season. Much valuable topsoil can be saved from erosion by building a series of check dams to collect the soil which would normally be carried away by waste water.

If gully erosion is to be checked, vegetative covering must be re-established. Organic matter must be incorporated in the soil, thereby increasing its water-holding capacity and thus decreasing the runoff. If gully erosion is to be checked and controlled, grazing must be regulated.

IRRIGATION AND DRAINAGE CONDITIONS IN CARBON COUNTY

Irrigation

Water requirements of crops are much greater in Carbon County than in sections where rainfall is heavier. Heavy rainstorms are generally of short duration and result in high runoff and little absorption; light rains quickly evaporate; consequently, neither heavy nor light rains are of great value to growing crops. Apparently, there is a direct relationship between irrigation and alkali control.

Three methods of irrigation are commonly practiced in this section: (1) Flooding, (2) furrow, and (3) corrugation. The flooding method is usually used on old alfalfa fields. The furrow method is applied to cultivated crops which are planted in rows. The corrugation method, which is the most important and the most widely used here, is a modification of the older and more widely known furrow method. The flooding method is not especially adapted to this locality, since the land is too steep and erosion readily results. Here the furrow and corrugation methods of irrigation are best suited and are most widely used; the chief difficulty in their use, however, is equal division of water in the head ditch among the large number of furrows. Corrugations are essentially small furrows spaced about 30 inches apart. When carrying the proper stream of water, they are supposed to irrigate the soil thoroughly, principally by a capillary movement of moisture. Shallow furrows are most effectual in spreading moisture horizontally at the soil surface. The most satisfactory corrugations are about 4 inches deep and from 4 to 6 inches wide. The length of the furrows depends upon the character of the soil; however, in general, furrows should be long enough to allow the water to run for approximately 24 hours. With the 24-hour plan, the water is turned into a new set of corrugations in the forenoon, the various streams being adjusted during the day so they do not erode the soil, overflow the corrugation, or otherwise cause damage. Under these conditions, the corrugation system is considered safe to leave during the night without further attention.

When barnyard manure is added to the soil it absorbs water more readily and retains the moisture longer. Irrigation water is more easily managed on soil which is well-supplied with humus in any form.

Pre-irrigation.- To pre-irrigate or not has long been a debatable question in this section. For some crops pre-irrigation has given highly satisfactory results, while for others it has little, if any, value. For potatoes, corn, and beans pre-irrigation is usually desirable. In general, pre-irrigation is desirable for crops whose seeds are planted deeper than 4 inches.

To insure germination for such crops as sugar-beets, millets, and truck garden crops in this region, the seedbed should be irrigated immediately after seeding, as already stated, the first irrigation being not only one of the most important of the entire season but usually the heaviest; for most satisfactory results, the soil should be almost saturated. The constant blowing of the spring winds in this area dries the surface soil and subsequent irrigations follow at rather frequent intervals. It is usually necessary, therefore, to irrigate sugar-beets three or four times before thinning. Sugar-beets require as much water to reach the thinning stage as they require during the balance of the season.

Drainage

The drainage problem in this area has always been an important one. In "alkali spots" in this and in surrounding territory, the water is near the surface. Proper method of draining these spots demands considerable attention. A number of farmers in different parts of Carbon County have installed tile drains, this system in nearly all cases having proved unsuccessful, however. The underground water does not percolate through the soil with any degree of regularity and the soil appears in many places to be almost impermeable.

Drainage and irrigation engineers who have examined these seeped spots believe that the water rises under pressure; unfortunately, the source of this underground water is not definitely known. In draining these spots, only that type of drain should be used which will cut off the course of the underground water. In some places it is thought that the impermeable subsoil barriers hold the water in "pockets." These barriers prevent the draining off of the water in the ordinary line drains, whether tile or open. It is not known whether water from nearby ditches or from adjacent fields heavily irrigated passes to a considerable depth and later rises. It is possible that the shale layers beneath the soil are so irregularly broken as to collect water in certain deep pockets, without much pressure from beneath. Whatever the nature of the water and salt accumulation, a decision will have to be reached sooner or later to determine whether it is more economic to install drains or to abandon the seeped spots.

CULTURAL METHODS ADAPTED TO THIS AREA

Seedbed Preparation

The nature of the soils and climatic conditions in this region indicate that fall-plowing, which is much more suited to this section than spring-plowing, should be practiced. Alternate freezing and thawing during the winter and early spring months gives the soil a much better tilth when the soil has been plowed in the fall. The moisture content of the soil at seeding time is much higher on fall-plowed than on spring-plowed land. On fall-plowed land early-seeded small grains germinate and mature with one less irrigation.

Immediately after plowing, either in spring or fall, harrowing the land with a spiketooth harrow to break up any clods has been found desirable. While it is not a general practice to harrow fall-plowed land, experiments has proved it to be a worthwhile practice in this region. To save moisture and to improve the tilth, fall-plowed land should be harrowed again in the spring as soon as it can be worked.

No experiments have been conducted as to best depth of plowing, but from observations it seems apparent that the ordinary 7- to 9-inch plowing is better than a deeper plowing of from 11 to 12 inches. Deep plowing, especially in the spring, does not absorb water as readily and it decreases crop yields; neither is the soil as friable as it is with the shallower plowing.

Use of Cultipacker

After the seedbed has been prepared by the usual cultural methods, it has proved desirable to thoroughly cultipack the land before seeding. The use of the cultipacker has been highly beneficial in this region as it tends to compact the soil, thus saving considerable moisture from evaporation. The cultipacker has been used to advantage in breaking crusts which tend to form after each rain(Fig.1, cover cut); these crusts are frequently so hard that the seedlings cannot break through. The cultipacker is one of the most useful machines on the farm, especially for seedbed preparation. The use of the cultipacker after seeding has proved to be of considerable value because of compacting the soil and making the establishment of the first irrigation less difficult. It was found that there was less tendency for erosion on the newly-seeded field, provided it had been thoroughly cultipacked after seeding.

Rotations

While a number of different rotations proved successful on the Carbon County Experimental Farm, a definite rotation system should be worked out for each farm. For most successful rotation results, however, the following factors should be observed: (1) A cultivated crop, (2) a legume crop, and (3) one crop where either barnyard manure or humus has been added to the soil. The type of rotation used depends largely upon type of farming practiced. The amount of irrigation water available is also a deciding factor. This, however, is a problem for each individual farmer to decide.

Table 5 indicates a series of successful rotations used on the Carbon County Experimental Farm from 1927-33, inclusive. Because alfalfa is one of the major crops in this section, the longer rotations are probably better adapted here than are the shorter ones.

Table 5.—Successful crop rotations, Carbon County Experimental Farm, 1927-33, inclusive.

Crop	No. Years	Length of Rotation
Grain and sweet clover	1	
Sweet clover	1	
Potatoes, corn, or beans	1	3 years
Grain and sweet clover	1	
Sweet clover	1	
Sugar-beets or potatoes	1	
Beans or corn	1	4 years
Grain and alfalfa	1	
Alfalfa	3	
Potatoes or beans	1	
Corn or sugar-beets	1	6 years
Grain and alfalfa	1	
Alfalfa	4	
Potatoes	1	
Sugar-beets	1	
Grain	1	
Corn or beans	1	9 years

FERTILIZER TESTS CONDUCTED, 1927 TO 1933, INCLUSIVE

Fertilizer tests were conducted on the Carbon County Farm from the time of its establishment in 1927. Both chemical and bacteriological tests showed this soil to be deficient in available phosphorus. A series of 28 plats was used for studying the effect of different fertilizers on crop production. Unfortunately, these tests were not conducted sufficiently long to definitely prove the real value of commercial fertilizers for all major crops(Table 6).

Table 6.—Results of commercial fertilizers and manure on yields of sugar-beets, corn, and wheat, 1927-33, inclusive.

Treatment[1]	Crop Grown		
	Sugar-beets (tons)	Corn (bus.)	Wheat (bus.)
No fertilizer	14.32	66.06	60.9
Nitrogen	12.50	64.27	60.0
Phosphorus	18.87	75.87	67.9
Potash	15.74	64.27	59.1
Manure	17.76	69.98	69.6
Nitrogen and manure	15.79	72.50	68.7
Phosphorus and manure	21.33	78.77	75.6
Potash and manure	18.69	79.77	69.6
Nitrogen, phosphorus, potash, manure	19.55	74.43	72.4
Average	17.17	71.76	67.0

[1]Applications were as follows:
Phosphorus (treble superphosphate) .... 125 pounds to the acre
Potash (potassium chloride) .... 125 pounds to the acre
Nitrogen (ammonium sulfate) .... 200 pounds to the acre
Barnyard manure .... 10 tons to the acre

Phosphorus fertilizers stimulated the beet seedlings during the early part of their development; this stimulation continued throughout the entire season. Ammonium sulfate had a decided retarding effect on the beet seedlings, which was noticeable throughout the growing season. Potassium fertilizer neither stimulated nor retarded the growth of beets to any marked degree.

From sugar-beet tests, it was evident that the use of barnyard manure supplemented with phosphorus is a limiting factor in their production. When barnyard manure and phosphorus were used together, not only was the acre-yield of beets increased but the sugar content as well. The use of barnyard manure and phosphorus gave the young beet seedlings a stimulation which aided in withstanding not only drought but disease and insect attacks as well.

The height of corn on manured plats was from 18 to 24 inches taller than on unmanured plats, regardless of other fertilizer treatments. The application of manure had no effect on the maturity of the corn. However, in each instance where phosphorus fertilizer was used the corn matured earlier; nitrogen retarded the date of maturity. Potassium fertilizer caused the corn to mature earlier than on either check or nitrogen plats, although it reached maturity on the phosphorus plats. Fertilizers had no effect on corn plant height.

The effect of different fertilizers on wheat was about the same as on corn. Phosphorus tended to cause the wheat to develop earlier in the season, this wheat being slightly taller than on check plats. Nitrogen fertilizer did not have the same retarding effect on wheat as it did on corn and sugar-beets. Potassium neither increased nor decreased the yield of the wheat crop.

In 1929 phosphorus fertilizer was applied on several alfalfa plats at the rate of 125 pounds to the acre. After this, no additional fertilizer was applied. Immediately after application of the fertilizer, the alfalfa began to show effects of its application. Table 7 indicates the percentage of increase in yields of alfalfa hay as a result of the addition of phosphorus fertilizer.

Each spring the alfalfa shoots started to grow several days earlier on phosphated plats than on check plats. Forage growth on fertilized plats was considerably heavier than on unfertilized plats, which was apparent in

Table 7.—Percentage of increase of alfalfa hay over check plats receiving no fertilizer. (Phosphorus fertilizer was applied at the rate of 125 pounds to the acre in 1929; no additional phosphorus or other fertilizer was applied.)

Year	Percentage of Increase over Check Plats			
	1st Crop	2d Crop	3d Crop	Average
1929	53.4	60.1	50.7	54.7
1930	42.5	61.4	53.2	52.3
1931	49.2	79.7	68.1	65.6
1932	66.6	62.8	67.6	65.6
1933	69.3	81.3	54.4	68.3
Average	56.2	69.0	58.8	61.3

greater number of leaves and in finer stems. This heavy growth tended to check the growth of alfalfa weevil which did considerable damage to forage on check plats.

Table 8.—Showing average percentage of phosphorus, calcium, magnesium, and crude protein in alfalfa hay from fertilized (phosphorus, 1929) and unfertilized plats.

Crop	P_2O_5 (Fertilized Plats) (%)				Check Plats (No Fertilizer) (%)			
	P	Ca	Mg	Crude Protein	P	Ca	Mg	Crude Protein
1st	0.299	3.26	0.66	15.00	0.203	2.26	0.63	13.84
2d	0.342	2.99	0.64	16.09	0.198	2.32	0.31	13.75
3d	0.271	3.09	0.66	15.45	0.173	2.47	0.36	13.10
Average	0.304	3.11	0.65	15.51	0.191	2.35	0.43	13.56

It will be observed from Table 8 that phosphorus fertilizer not only increased the yield of hay but that it also increased the amount of essential mineral foods and crude protein in the hay.

CROP-TESTING EXPERIMENTS

Many different crops were tested on the Carbon County Experimental Farm to determine, if possible, those best suited to local conditions. Several new varieties were introduced, some of which proved superior to those formerly grown in this section. A number of crops were tried which had been highly recommended for this region; however, when grown for a few years here these crops did not prove satisfactory. All land was highly fertilized with barnyard manure, except for those plats used for fertilizer tests.

Field Crops

Alfalfa.- Alfalfa is one of the principal crops grown in this section, formerly considerable seed being produced. The most widely-grown alfalfa variety is Utah Common; tests conducted on the Carbon County Experimental Farm have proved this to be one of the best varieties for this section. Other varieties which have done well and which may be safely recommended here are Grimm, Ladak, Hardigan, Idaho Common, and Dakota Common. There does not seem to be any great degree of difference in the hardy varieties. Approximately 3 acre-feet of irrigation water are required to produce three cuttings of alfalfa hay, the average yield of hay being about one ton for each cutting. The use of phosphorus fertilizers increased the acre-yield to 4 or more tons for the season.

Corn.- Corn is yearly becoming a more important crop for this section of the state, being used for both silage and grain. However, more attention should be given to this crop as it fits well into most rotation systems. Generally speaking, the earlier varieties of corn are best adapted to this region. Yield data from some of the outstanding corn varieties which have been grown on the Carbon County Experimental Farm are shown in

Table 9. This crop can be produced with less irrigation water than any other major crop, requiring but an average of 1.5 acre-feet of water to produce a corn crop. It has been quite definitely proved that more cultivation and less irrigation produces superior corn. If weeds are allowed to grow during the early part of the season, it is impossible to obtain a satisfactory corn crop.

Table 9.—Average yield data, from leading corn varieties, Carbon County Experimental Farm, 1927-33, inclusive.

Variety	Shelled Corn Acre-yield(bus.)	Time of Harvest
Golden King	81.4	Sept. 16
Gooding's White Dent	81.1	Sept. 20
Extra Early Minnesota No. 13	80.2	Sept. 9
Minnesota No. 13	79.5	Sept. 19
Extra Early Rustler	77.9	Sept. 10
Gooding's Yellow Dent	71.2	Sept. 20
Northwestern Dent	63.6	Sept. 10
White Flint	54.7	Sept. 1
Yellow Flint	50.3	Sept. 1

Extra Early Minnesota No. 13 is probably the most widely grown corn variety in this section. Many growers believe the flint varieties to be superior for local conditions, but actual tests proved the flint varieties to be lowest yielders. They are not considered as suitable for either silage or grain as are the dent varieties.

Barley.- Barley is one of the most promising crops for this section, from 65 to 80 bushels to the acre being produced with reasonable care. In testing the resistance of different crops to alkali, it has been found that barley can withstand a heavier concentration than any other grain crop. Trebi has proved to be the highest yielding variety grown on the Carbon County Experiment Farm(Table 10). Considerable damage is done each year by covered smut; however, this can be controlled by treating the seed with formalin.

Table 10.—Average acre-yield of six leading barley varieties, Carbon County Experimental Farm, 1927-33, inclusive.

Variety	Acre-yield(bus.)	Average Height(in.)
Trebi	91.7	26
Atlas	79.7	26
Colorado 3192	78.3	26
Coast	75.2	25
Sacramento	69.8	25
Colsess	67.5	27

Barley yields, like those of other cereals, can be materially increased by proper methods of field and soil management. Under proper soil management, attention must be given to crop sequence not only from the standpoint of getting the crop started but also to discourage growth and spread of weeds. Approximately 2.5 acre-feet of irrigation water is required to produce a normal crop of barley. Under local conditions, barley is somewhat more subject to lodging than oats. Barley produces more pounds of feed per acre than oats and matures from five to ten days earlier.

Wheat.- Like other cereals wheat, when properly managed, does well on these soils; it can be produced with approximately 2.5 acre-feet of irrigation water. It is desirable to seed wheat on fall-plowed lands, since it will germinate and emerge without an irrigation. Seeding should be done as early in the spring as possible, some of the best yields being obtained when seeding has been done by the first part of March. For highest yields, at least 2 bushels of clean seed should be planted to the acre; this seed should be first treated with either copper carbonate or formalin for smut control.

Table 11.—Average acre-yield of six leading wheat varieties, Carbon County Experimental Farm, 1927-33, inclusive.

Variety	Acre-yield(bus.)	Average Height(in.)
Dicklow	60.6	39
O1-24[1]	57.1	33
Federation	55.9	33
Q-80[1]	55.6	34
Q-227[1]	55.3	35
Baart	52.4	35

[1]Hybrids developed by Utah Agricultural Experiment Station.

Dicklow, the principal variety of wheat recommended for the Carbon County section, proved to be the outstanding variety tested on the Experimental Farm(Table 11). Dicklow is usually of a high quality. Some of the hybrids introduced by the Utah Agricultural Experiment Station proved to

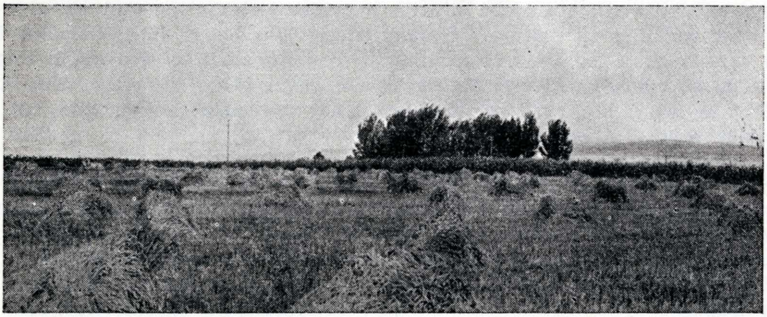

Figure 3.—Field of Dicklow wheat grown on Carbon County Experimental Farm.

be well-adapted to local conditions; eventually they may find a place as a main-crop variety in this area. As with other crops, highest yields are produced on soil which has been well-supplied with barnyard manure. Tall-growing wheat varieties are usually better adapted to local soil conditions than short stiff-strawed varieties.

Oats.- There is still some question as to whether oats or barley is the better feed crop to be grown on irrigated land. Choice is determined by a number of factors: (1) Yields of feed per acre, (2) date of maturity, (3) amount of irrigation water necessary to produce a crop, (4) cost of production, (5) feeding value, (6) value of the crop per acre if sold as a cash crop, and (7) yield of straw. Usually oats are regarded as a better grain than barley for feeding horses and young growing stock, while barley is preferable for fattening. Results of experiments conducted on the Carbon County Experimental Farm proved that barley produces more feed per acre. Cost-of-production and irrigation requirements are approximately the same. Oats yield more straw and are more easily harvested than barley.

Swedish Select is the most popular barley variety because it produces a high yield of white, plump, heavy grain. Colorado 37 produces more straw per acre than other varieties and would probably be better adapted to low-producing lands than the other varieties. In many sections Markton is considered the outstanding variety but is not always the choice because of the yellowish cast to its grain.

Table 12.—Average acre-yield of seven leading oat varieties, Carbon County Experimental Farm, 1927-33, inclusive.

Variety	Acre-yield (bus.)	Average Height (in.)
Swedish Select	94.5	33
Colorado 37	91.5	42
Victory	88.7	33
Markton	88.4	30
O.A.C. 144	83.6	35
Idamine	75.5	31
Golden Rain	73.2	34

Beans.- Beans have always done exceptionally well on soil types in this region. They also lend themselves admirably to different crop rotations. All standard varieties tested have done well. Beans apparently withstand alkali in the soil better than some recommended alkali-tolerant crops. They require less irrigation water than most of the cultivated crops (approximately 2 acre-feet of water to produce a crop); however, this is more water than is required for corn (1.5 acre-feet). In this section Pinto beans have always been one of the heaviest yielders as well as one of the first varieties to mature. Usually, there is a better local demand for this variety than for any of the others. The Robust Pea is a small round white bean, whose quality is not as high as some other varieties. The Red Kidney is not a high yielder, but its quality is considered by many to be superior to the other varieties.

Table 13.—Yield of six leading varieties of beans, Carbon County Experimental Farm, 1927-33, inclusive.

Variety	Acre-yield (lbs.)	Date of Harvest
Pinto	2076	Sept. 4
Robust Pea Bean	2060	Sept. 5
Great Northern	1966	Sept. 10
White Wonder	1936	Sept. 9
Red Kidney	1825	Sept. 12
Red Mexican	1683	Sept. 6

Sugar-beets.- Sugar-beets have always been one of the outstanding crops grown on the Carbon County Experimental Farm. They are not nearly as sensitive to the kind of soil in which they are grown as are most crops. Sugar-beets require more irrigation water than any crop grown in this region, an average of approximately 4 acre-feet of water being required. It is necessary to irrigate the seedbed immediately after the beets are seeded; frequently two or three irrigations are necessary before the beets reach the thinning stage. Contrary to the usual practice in most sections, in the Carbon County region the heaviest irrigations of the season are the first ones, which are applied in alternating rows. Considerable care must be taken to distribute the water evenly in all rows and to give all parts of the field an equal irrigation, special care being taken to avoid washing and flooding. When the soil is flooded, it crusts and the beet seedlings are injured. The first irrigation is the most important of the entire season, this irrigation largely determining the percentage of stand. Once the beets reach the thinning stage, with reasonable care a good crop is practically assured.

Sugar-beets respond readily to the application of barnyard manure. Tests conducted show that the highest yields of both beets and sugar content were obtained when barnyard manure was supplemented with phosphorus fertilizers. Sugar companies recommend to their growers that phosphorus fertilizers be applied at planting time.

Beet seed should be planted in the spring as soon as soil conditions are favorable for its germination and growth. Best yields are usually obtained from early planting because it gives them a longer growing season.

The best time to seed beets is from April 15 to May 1. On this particular soil it is advisable to plant the seed from 1.5 to 2 inches deep and to use from 15 to 20 pounds of seed to the acre.

One of the most common handicaps in sugar-beet production in this particular section is soil-crusting. Flooding and rains are factors in crust formation. The nature of the beet seedling is such that it is highly important to maintain a loose mulch on the field during germination and during the young seedling stage. Crusting causes many of the young seedlings to die, resulting in a greatly reduced stand. Crusting can be broken up by cultivation of rows before the plants have reached the surface or while the plants are still in the seedling stage. Light harrowing is recommended; however, the corrugation roller or cultipacker is usually the best implement to use.

Thinning should begin when the beets have four leaves, after which this operation should be rushed to completion. Small beets are easier to thin and suffer less from crowding than large ones. Highest yields are obtained when beets are spaced from 10 to 12 inches apart in the row. Thinning is probably the most important operation of the season.

During some years, considerable injury was done by the sugar-beet leafhopper or "white fly," which caused the beets to contract curly-top disease. It was yearly observed that curly-top was not as prevalent on beets grown on highly fertilized land as on soil with low fertility. Early-seeded beets did not tend to develop this disease as readily as late seedings. Certain curly-top-resistant strains of sugar-beets have been developed by the United States Depratment of Agriculture, some of these strains having been grown on the Carbon County Experimental Farm, where they proved to be highly resistant to curly-top disease and showed promise of becoming leading varieties.

The average stand obtained was from 12 to 20 tons of beets to the acre, yields being largely determined by fertility and cultural methods practiced.

Potatoes.- Generally speaking, Carbon County has not been considered as a potato-producing section, the common practice being to import them. Tests conducted on the Experimental Farm, however, showed that this section should export rather than import potatoes. The warm days, the cool nights, and favorable soil conditions are conducive to the production of high-quality potatoes. In tests on the Carbon County Farm, potatoes did best on pre-irrigated land. Average acre-yields of the six leading potato varieties tested are shown in Table 14.

Table 14.—Average acre-yield of six leading potato varieties, Carbon County Experimental Farm, 1927-33, inclusive.

Variety	Acre-yield (bus.)
Brown Beauty	339.7
Rural	316.2
Early Eureka (Idaho Rural)	303.4
Bliss Triumph	267.6
Cobbler	264.3
Blue Victor	227.7

While Brown Beauty proved to be the highest yielder, it was not generally adapted to the wide variation in soil types found in this region. It did best on soil which was in a high state of fertility, while on poor and average soils it yielded less than most varieties. Rural, Early Eureka (Idaho Rural), Green Mountain, etc. proved to be better varieties for this section. Rurals were consistently high yielders on most soil types; however, they had a tendency to develop many over-size tubers, a fault which can be corrected, however, by close planting. Cobblers were the earliest-maturing potatoes tested. They produced marketable tubers ten days before either Bliss Triumph or Early Ohio. Bliss Triumph had a local demand, as many people prefer potatoes with a magenta skin; this variety, however, does not possess good keeping qualities.

Miscellaneous Crops

Flax.- Several different varieties of flax were tested on the Carbon County Experimental Farm to determine whether or not this crop was of economic importance in this section of the state. Flax was grown on highly fertilized soil and special care taken of the plants during the growing season. Tests for four years indicate that it is doubtful if flax has any place as a commercial crop in this region. It is practically impossible to harvest a commercial crop because of its height. Table 15 gives the average acre-yield of the five leading flax varieties tested. There is little difference in yield or in height of different vareties; yields are too low to recommend flax as a profitable crop.

Table 15.—Average acre-yield of five leading flax varieties, Carbon County Experimental Farm, 1930-33, inclusive.

Variety	Acre-yield (bus.)	Average Height (in.)
Buda	17.3	22.6
Rio	15.7	19.6
Bison	15.5	20.3
Redwing	14.7	18.6
Linota	14.6	19.3

Sorghum.- Sorghum is another crop which probably does not have a place in the cropping system of this section, where it did not prove to be a successful crop. Possibly the relatively high alkali content of the local soil may be the limiting factor in its production. Yields obtained are irregular, the yield of some varieties for one year being comparatively high, while for the following year there was a low yield. Many varieties were tested, but none was consistently better than another. The following varieties proved to be superior, the acre-yields ranging from 20 to 40 bushels of shelled grain: Red Amber, Feterita, Dwarf Hegari, Early Kalo, Dwarf Freed, and Dakota Amber. None of these varieties is recommended for local growing.

Millets.- Several different varieties of millets were tested, some apparently being well-adapted to local conditions. Proso or hog millet was the outstanding variety tested. Proso was one of the best "catch crops" for this section; it matured in a short time and used comparatively little water. Proso can be used for either a grain crop or as a hay crop. When cut in mid-season for a hay crop, Proso produces a second crop which frequently develops mature seed; it tends to give maximum returns when the seeding is done just before warm weather. Its greatest value is obtained by fairly early seedings, by cutting a hay crop in mid-season, and by having sheep, hogs, or poultry harvest the grain crop.

Sudan Grass.- From tests conducted in this section, indications are that as an annual crop Sudan grass may have a definite place in the crop program. Yields of cured hay were slightly less than the alfalfa. Best results were obtained by seeding Sudan grass when the soil became warm at corn-planting time, or a little later. Highest yields were obtained when the first heads appeared. Sudan grass furnishes abundant pasturage from mid-summer until frost time. It is not exacting in its soil requirements, although it naturally does best on a well-drained fertile soil; it is more or less alkali-tolerant.

Pasture Grasses.- Probably one of the greatest needs of this section is a good pasture system. It is doubtful of grasses and clovers, highly recommended in other localities, would be adapted to soil and climatic conditions of this part of the state. Some tests were conducted on the Farm for the purpose of determining which grasses and clovers thrived best here; however, these tests were not conducted sufficiently long to definitely recommend or to condemn any variety or varieties.

The following grasses and clovers did well on test plats and apparently are well-adapted to local conditions: Awnless brome grass, orchard grass, meadow fescue, tall meadow oat grass, white Dutch clover, and alsike clover. Grasses which proved fairly successful and which may have a place in establishing permanent pastures in this section are timothy, redtop, Kentucky bluegrass perennial rye grass, western wheat grass, and crested wheat grass.

In this section one of the main difficulties encountered in getting a good pasture is in obtaining a desirable stand. It is extremely difficult to start the small seeds of most grasses. It is possible that better stands might be secured if seeding were delayed until about the middle of June or the first of July, when there is little wind and when the soil does not dry out so rapidly. After a desirable seedbed has been prepared and the seed sown, the soil must be completely saturated with water and then kept wet until the seeds have germinated.

Under Alkali Land Conditions

A limited number of experiments were conducted on the Carbon County Experimental Farm to determine what crops might grow best on soil heavily impregnated with alkali salts. The plats were so arranged as to run from an area of comparatively little salt to one which was so heavily impregnated that plant life was impossible. Asparagus, barley, oats, Sudan grass, sugar-beets, and yellow and white blossom sweet clover were grown. Of these crops, asparagus was able to withstand the greatest concentrations of alkali salts; it seemed to thrive in a concentration of 11,335 parts per million of salt(the chief salt being sodium sulphate) and its quality did not seem to be affected by the alkali. Sunflowers were next to asparagus in ability to withstand alkali salts. Yellow sweet clover was more resistant to alkali than white sweet clover. Barley was more resistant than oats, and Sudan grass was in the same class as oats. Sugar-beets, if successfully grown through the seedling stage, made satisfactory growth in these soils, which are highly impregnated with alkali salts.

From the limited number of studies made it would seem that asparagus, sunflowers, barley, and sugar-beets may have a place in the reclaiming of alkali lands similar to those in this section of Utah.

MISCELLANEOUS INVESTIGATIONS

Vegetable Garden Possibilities

A small plat of ground on the Farm was used to determine which garden crops were best adapted for this section. As with some of the field crops, securing a desirable stand proved to be the most difficult problem of the entire season. Immediately after sowing the seeds, it was necessary to irrigate the seedbed, thus assuring germination. The more humus in the soil, the less irrigation required and the easier it was to obtain a desirable stand. The quality of vegetables grown in the home garden was always considerably better on highly fertilized soil.

All standard vegetables, if given reasonable care and cultivation, produced satisfactory crops. Because of local soil conditions, it was difficult to produce high-quality onions, better onions being produced from plants and sets than from seeds. The following vegétables were also grown, high yields being obtained for each: Asparagas, carrots, peas, beets radishes, turnips, cabbage, lettuce, kohl-rabi, garlic, chard, snap beans, cucumbers, pumpkins, squash, sweet corn, tomatoes, parsnips, rhubarb, horseradish, multiplier onions, and spinach.

Each individual garden in this section should provide space for permanent vegetables and small fruits, the location interfering neither with the plowing of the garden nor with the cultivation of annual vegetables. These permanent vegetables should probably consist of a bed of asparagus, a few plants of horseradish and rhubarb, and a row or two of everbearing raspberries and strawberries.

St. Regis is the only variety of everbearing raspberries which has been successful in the farm garden here, other varieties tending to winterkill and lacking dependability. St. Regis winterkills, but the new shoots produce a crop of fruit in the late summer and early fall. The Mastodon variety of ever-bearing strawberries was the best. One-crop berries were not successful as they bloomed so early in the spring that most of the fruit was killed by frost.

Floriculture in the Home Garden

Different varieties of flowers and shrubs were tested on a small plat of land. The object of this test was to find varieties of flowers and shrubs best adapted to local conditions. Each farmstead should have its permanent flower garden, not only in this section but in all sections. Because of the flower show contests conducted by the various mining camps in Carbon County, there is a growing interest in floriculture in this vicinity.

Of the annual flower varieties tried, the following proved highly satisfactory: Calliopsis, zinnia, poppy, petunia, calendula, marigold, cosmos, larkspur, verbena, castor oil bean, scabiosa, morning glory, and alyssum. Perennial flowers which did especially well include Oriental poppy, delphinium, rudbeckia, hardy aster, iris, sweet-William, gaillardia, hollyhock, and Shasta daisy. Dahlias and gladioli also did exceptionally well.

Shrubs which proved satisfactory and are recommended for this region include flowering almond, weigela, spirea, mock orange, forsythia, snowberry, butterfly bush, and barberry.

Windbreak and Woodlot Studies

A plat of ground was selected on the Farm in 1931 for testing different varieties of trees suitable for windbreaks and woodlots. Comparatively few trees are grown on farms in this section, the principal ones being native cottonwoods and boxelders, and additional trees should be planted. Because of soil and climatic conditions, however, only a limited number of trees are adapted to this region, the Siberian elm and a Russion olive being best adapted. The Siberian pea tree made a satisfactory growth but was not grown sufficiently long for any definite recommendations to be made as to its local adaptability. The Siberian elm is best adapted for woodlots and the Russian olive for windbreaks. The high alkali content of the soils apparently does not affect the growth of these trees and neither variety is affected by winterkilling.

Trees should be cultivated at regular intervals, the same as row crops of potatoes or corn are cultivated. Cultivation between trees with a springtooth harrow, a two-way disk, or a cultivator prevents the growth of weeds and causes the trees to make a much more rapid growth. The tendency of the soils of this region to form hard crusts on the surface materially reduces the rate of growth of young trees, if they are not cultivated.

GENERAL STATEMENT

The outstanding characteristics of the soils of this region make farming extremely complicated, the high alkali content and lack of humus adding materially to this problem. Comparatively little experimental work has been done on similar soils, and literature on soil management of this type is meager. The limited amount of experimental work done, however, points to the urgent need for more work on soil management and crops adapted to the Carbon County region.

The control of soil alkali is a problem of considerable importance and appears to be extremely difficult during certain years because of climatic conditions and because of the amount of irrigation water applied to the soil. The control of alkali is still in the experimental stage; it is a known fact, however, that excessive irrigations increase the percentage of alkali. Apparently, there is no relationship between alkali content and soil fertility.

One of the most difficult problems of crop production is to have the plants pass successfully through the seedling stage. Once the crop has passed this stage, satisfactory returns are practically assured, provided reasonable care and cultivation are given. The addition of humus in any form gives better tilth and increases the percentage of emergence. The water-holding capacity of a soil is also increased by the addition of humus.

Phosphorus fertilizers supplemented with barnyard manure materially increase most crop yields. Tests indicate that soils in this region are generally well-supplied with total phosphorus, although the amount of available phosphorus for plant growth is limited.

Additional investigation on gully erosion is necessary. The nature of the soils of this region makes them especially susceptible to erosion. Lack of controlled grazing is partly responsible for erosion increase.

A method of draining "alkali" or "seep spots" is another unsolved problem. Drainage and irrigation engineers have different opinions as to the proper methods of draining these areas. The slow rate at which the under-groundwater percolates through the soil makes drainage extremely difficult.

SUMMARY AND CONCLUSIONS

The soils of this section are classified as belonging to the Billings series and are generally known as a very fine sandy loam. All soil is underlain by Mancos shale, which contains large amounts of soluble salts. These soils are low in organic matter and tend to absorb water slowly. The addition of humus to the soil increases its water-holding capacity and decreases soil-management problems.

Practically every farm in this region has its own soil-alkali problem caused by over-irrigation and canal seepage. Of all crops tested, asparagus, sunflowers, barley, and sugar-beets are most resistant to alkali.

Erosion gullies are increasing at an alarming rate in this region, for which over-grazing is responsible to a large extent.

Fall-plowing is better suited to local conditions than spring-plowing. The cultipacker is a most useful implement for seedbed preparation.

For deep-seeded crops, pre-irrigation has given best results. The corrugation method of irrigation has proved the most satisfactory and is the most widely used in this section.

Phosphorus fertilizer in the form of treble superphosphate increased the yield of sugar-beets, corn, wheat, and alfalfa. Tests indicate that barnyard manure supplemented with phosphorus is one of the limiting factors in crop production. Nitrogen and potassium fertilizers neither increased nor decreased crop yields. Phosphorus fertilizer continued to give increased yields of alfalfa after 15 crops had been harvested; it also increased the phosphorus, calcium, magnesium, and crude protein content of hay.

Corn is gradually becoming a highly important crop in this region. Early-maturing corn varieties are recommended for silage and grain. Corn requires less irrigation (1.5 acre-feet) than does any other major crop.

With proper care, barley, wheat, and oats do well in Carbon County. Trebi has proved to be the best variety of barley tested. Dicklow was the outstanding variety of wheat and Swedish Select the best oat variety.

Beans have always done well on these particular soil types and fit well into the different rotations. Pinto beans proved to be the best variety.

Sugar-beets are one of the outstanding crops grown here. They use approximately 4 acre-feet of water each season. Beets responded readily to the application of barnyard manure supplemented with treble superphosphate.

Rural and Early Eureka are the best main-crop potato varieties. Cobblers have proved to be the best variety for early planting.

Nearly all vegetables produced satisfactory crops for the home garden. Ever-bearing raspberries and strawberries apparently are especially adapted to this section.

Siberian elm and Russian olive trees are recommended for windbreaks and woodlots in the Carbon County section.

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